Application of optical fibres for blade load measurement and condition monitoring

H.B. (Ben) Hendriks

Albuquerque, February 2004

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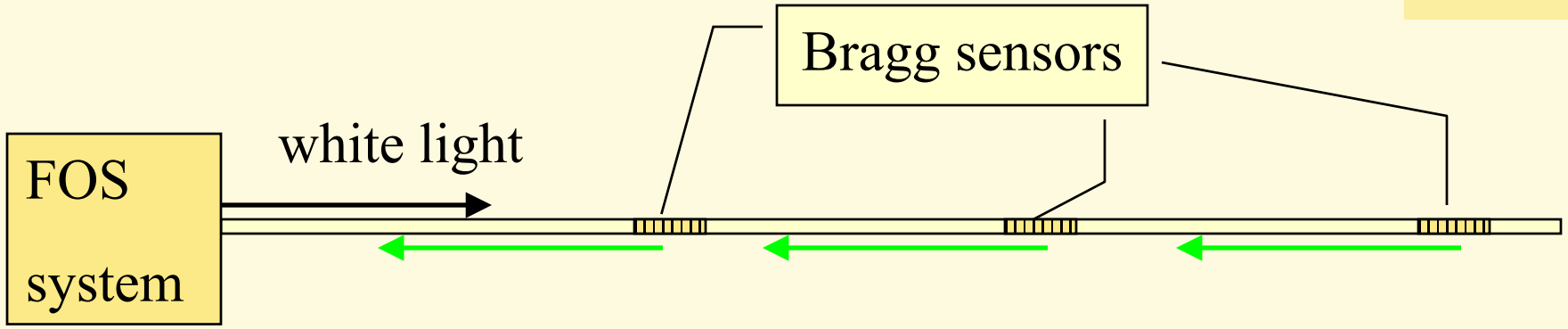
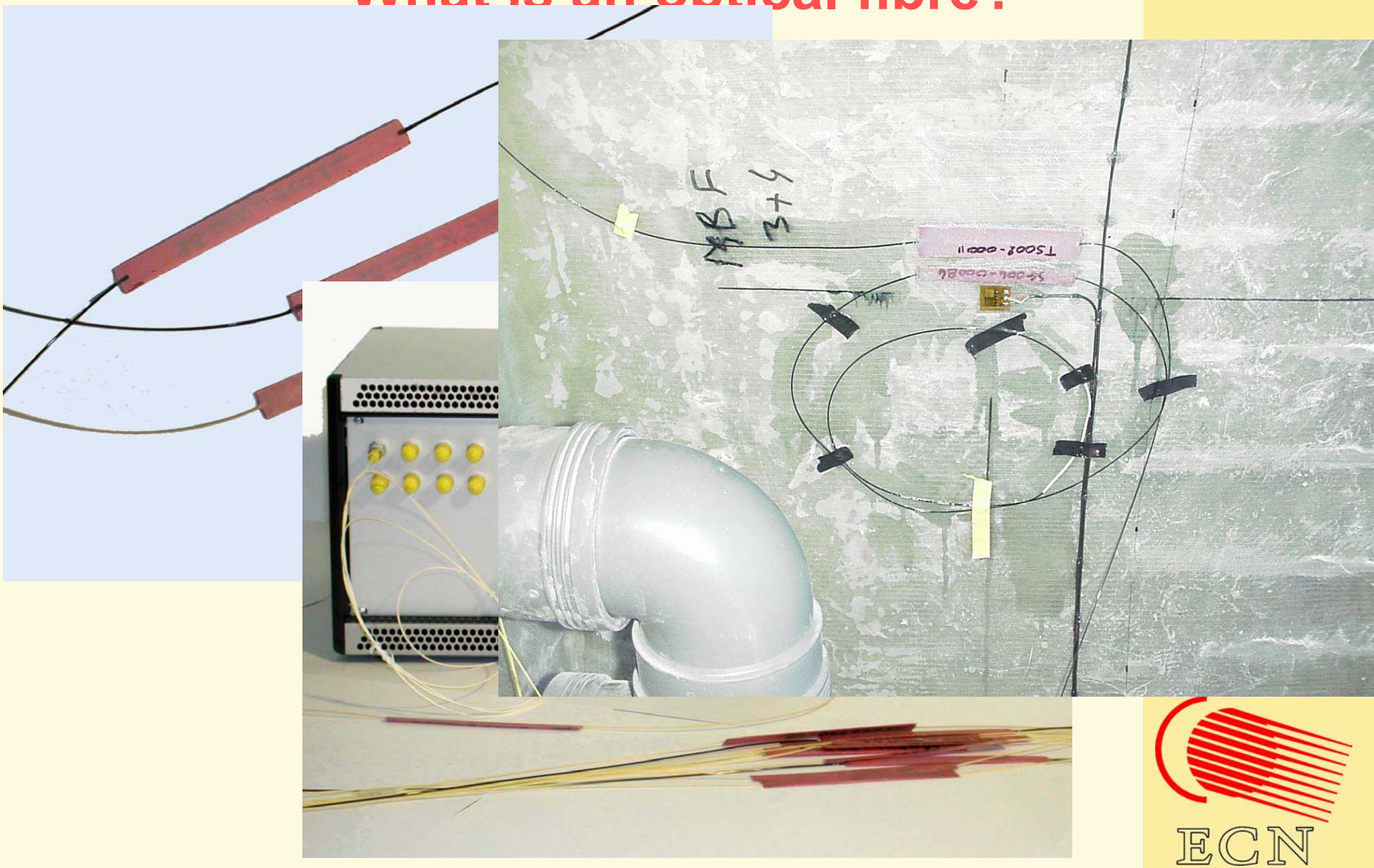
What is an optical fibre?



Reflected light with wavelength equal to distances between “scratches”

What is an optical fibre?



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Contents of presentation

- Introduction to ECN
- Introduction to condition monitoring
- Possibilities of optical fibres
- Test set-up
- Experience with optical fibres
- FOBM system layout

Introduction to ECN

Priority Areas

- Solar (PV)
- **Wind Energy**
- Biomass
- Clean Fossil (Fuel Cells)
- Policy Studies
- Energy Efficiency in the Industry
- Renewable Energy in the Build Environm

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Introduction to ECN

Wind Energy

"With 45 employees the unit holds a strategic position between universities and industry covering all relevant wind energy disciplines; from trouble shooting to long term R&D, from training courses and design support to wind farm development and risk management."

Four groups

- Wind Farm Development
- Wind Turbine Technology
- Wind Farm Operation
- Experiments

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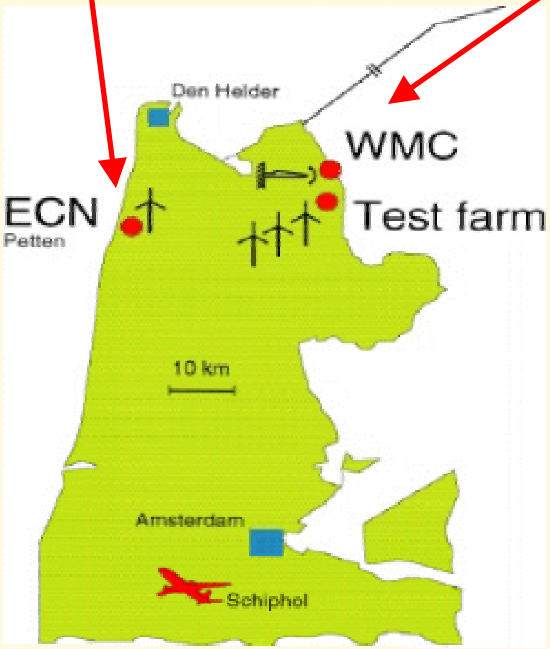
Introduction to ECN

Knowledge Centre WMC
(Wind turbine Materials and Constructions)



ECN Wind Turbine Test Farm Wieringermeer

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Projects / Partners / Persons

DOWEC

(Erik Korterink,
Arno van der Werff)

- NEG Micon Holland
- LM Glassfibre Holland
- Ballast Nedam
- Van Oord ACZ
- Delft University of Technology

FOBM

(Luc Rademakers,
Theo Verbruggen)

- NEG Micon Holland
- FOS
- NGUp
- Baas R&D

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Need for condition monitoring in wind energy

- Preventing damage and directly related costs
- Preventing revenue losses in case of damage, most significant for offshore wind energy
- Limiting the number of attendances (time to repair or inspection)
- Optimum planning using predicted remaining lifetime (seasons offshore)

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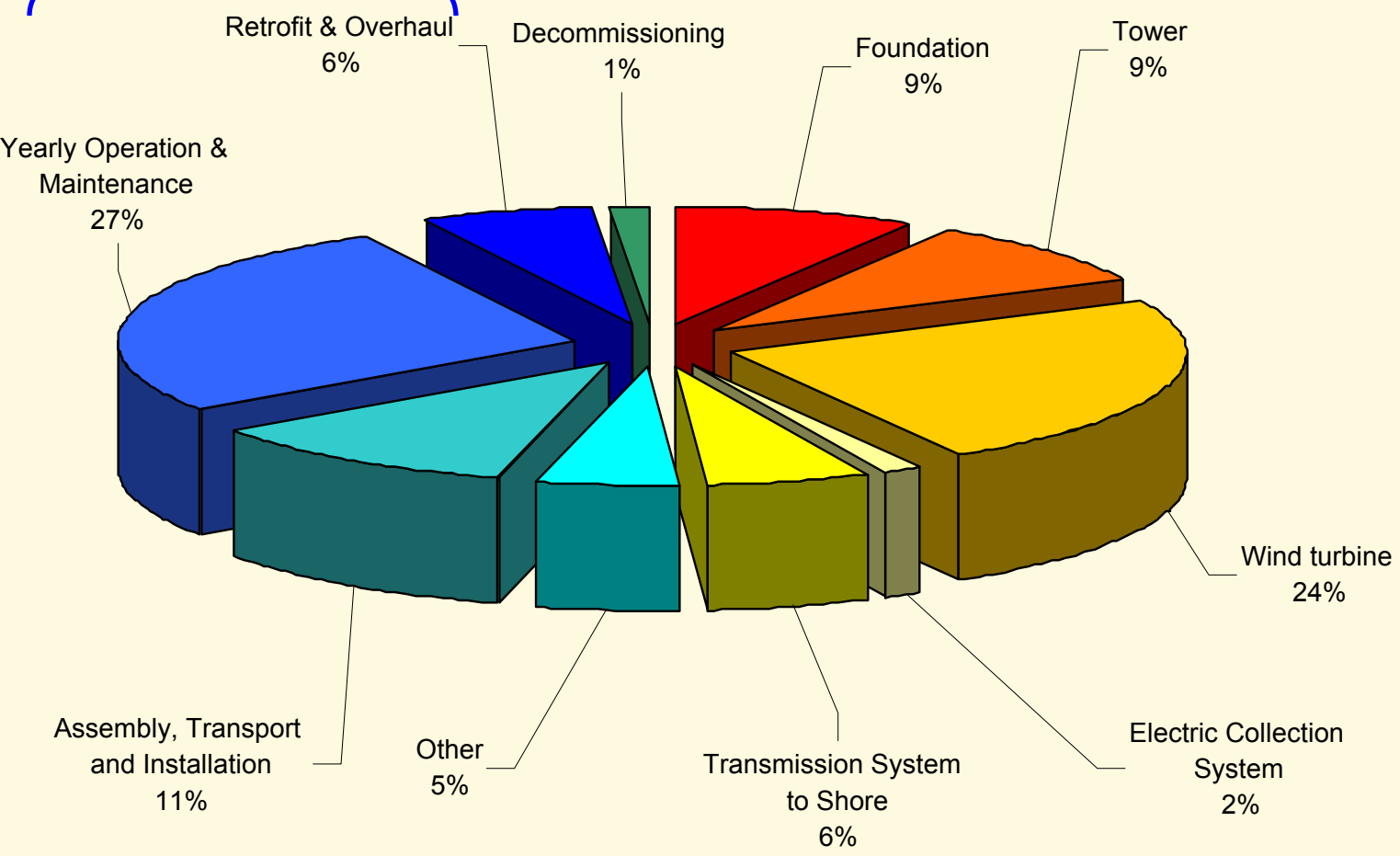
Need for condition monitoring

33%

+ revenue losses



Break-down of Generating Costs Offshore Wind Energy

Results from the DOWEC study

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Condition monitoring for wind turbines

Condition monitoring is a proven method in other branches. The application in wind energy differs from the present application:

- Stochastic loading versus stationary operation
- Preventing damage versus enlarging preventive maintenance period
- Trade-off between higher investment and lower damage costs

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Condition monitoring for wind turbines

Condition monitoring is applicable to many wind turbine components:

- Blades
- Drive train
- Main bearing
- Generator
- General behaviour (degradation of power curve)
- Other…

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Possibilities for optical fibres

All possible failure modes of the blades have been investigated on possibilities for condition monitoring systems

Some can be detected by a strain measurement; on basis of a changed strain distribution or a change in natural frequency or cumulative load spectrum

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Possibilities for optical fibres

Trailing edge transverse crack

Trailing edge transverse cracks (details, source Allianz))

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Possibilities for optical fibres

Supposed of a measuring strains with an optical fibre versus classical copper strain gauges:

- Non-conductive, important for lightning
- More simple instrumentation
- More reliable in time

Advantages to be demonstrated in 2 year R&D project

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Possibilities for optical fibres

Topics of research:

- Accuracy of measurement (zero drift, temperature influence)
- Reliability in time (opto-electronics, sensors)

Next to field tests, laboratory experiments are planned in the WMC

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Test set-up

The DOWEC demonstrator / NM92 wind turbine at the ECN test site

Foto Rob Nijda

Test set-up

108 m meteo mast

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Distributed system:

- front-ends at different locations: sensor power supply and all signal conditioning, EMC proof
- glass fiber connections
- one central host pc: data collection and back-up, transfer to ECN database

st set-u

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Fibre Optic Blade Monitoring (FOBM)

Applications for Wind Farm Operators

1. Converting raw data (*strain*) into meaningful parameters (*loads, vibrations*) for blade monitoring :

   - Assessment of loads (*extreme loads, fatigue load spectra, consumption of lifetime*)
   - Assessment of health and degradation
   - Design verification using design data

2. Informing operators about required O&M effort of blades

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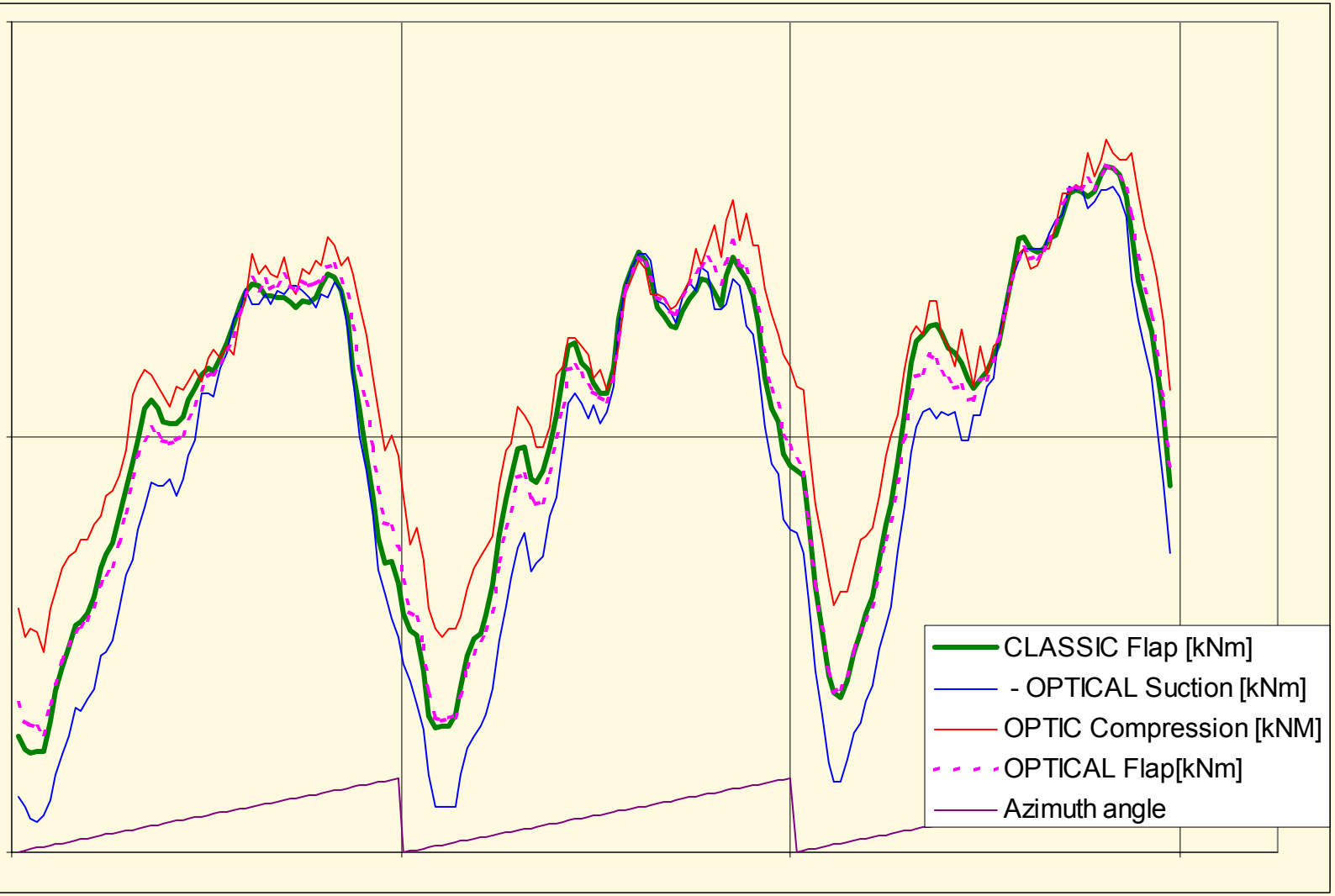
Example of time series



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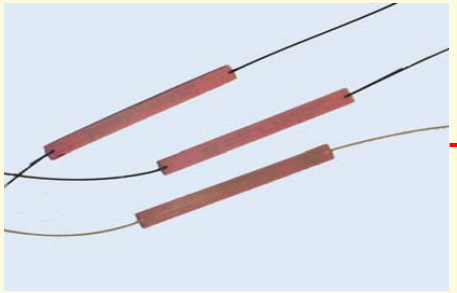
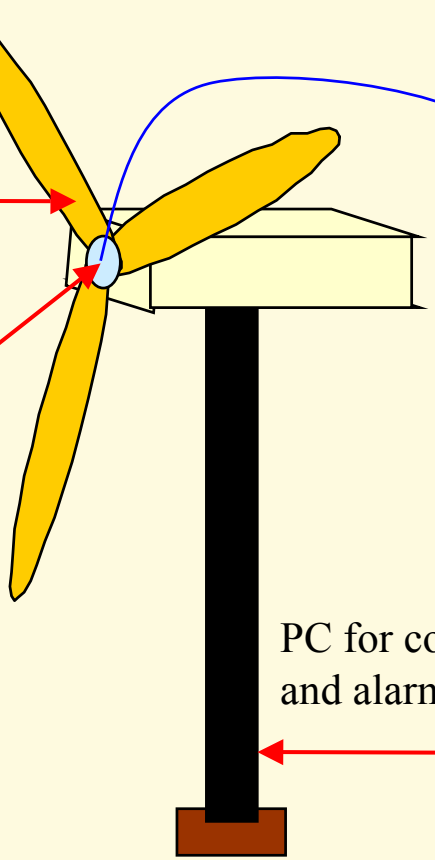
FOBM: Hardware



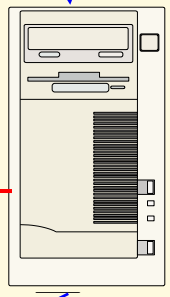
Optical fibres
in blades

Data logger
in hub



Strain,
Loads,
Spectra,
...etc.

PC for control
and alarm



Wind speed, Pitch angle
Power

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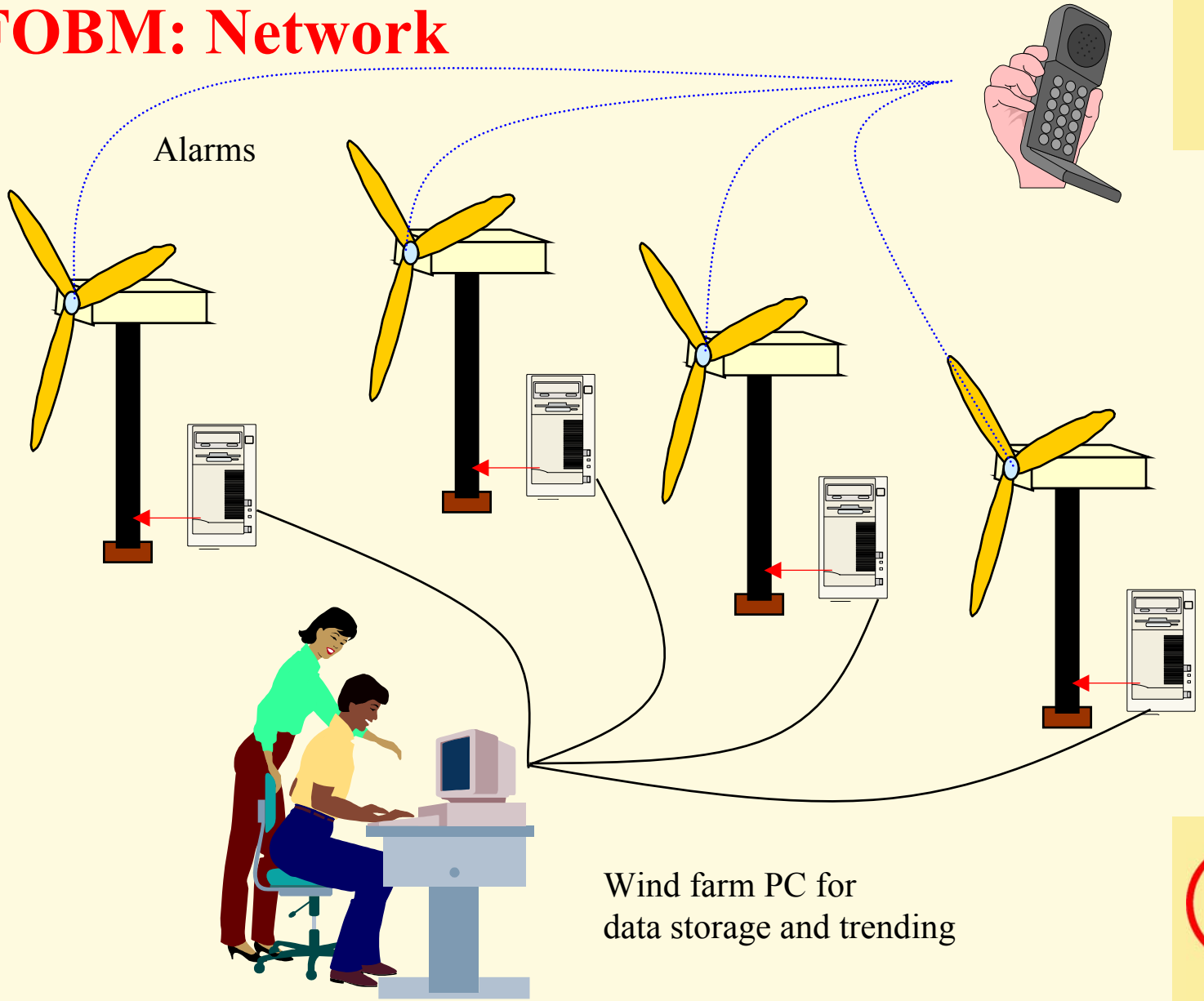
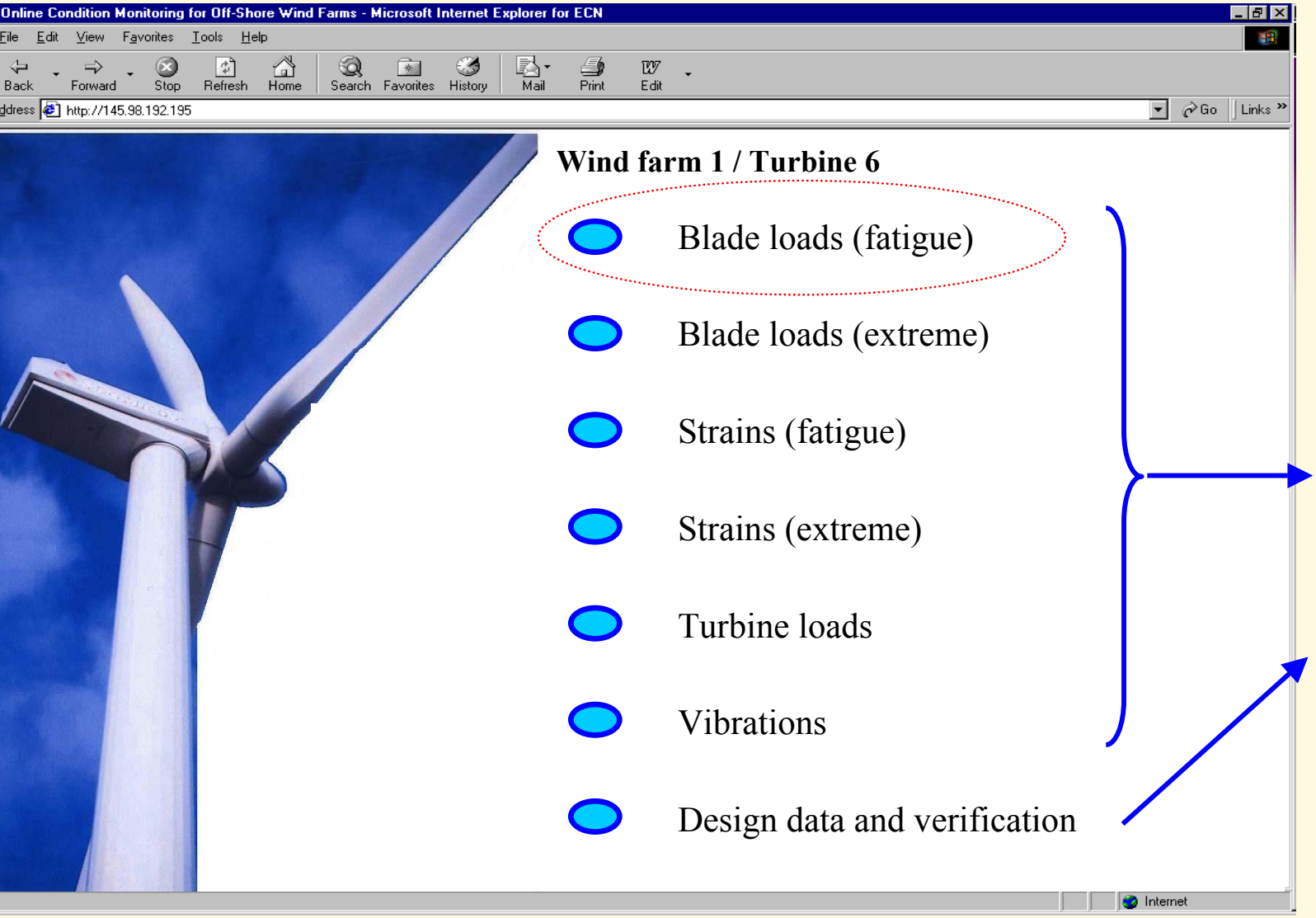
FOBM: Network



FOBM: Remote Access



No design data needed

Design data needed

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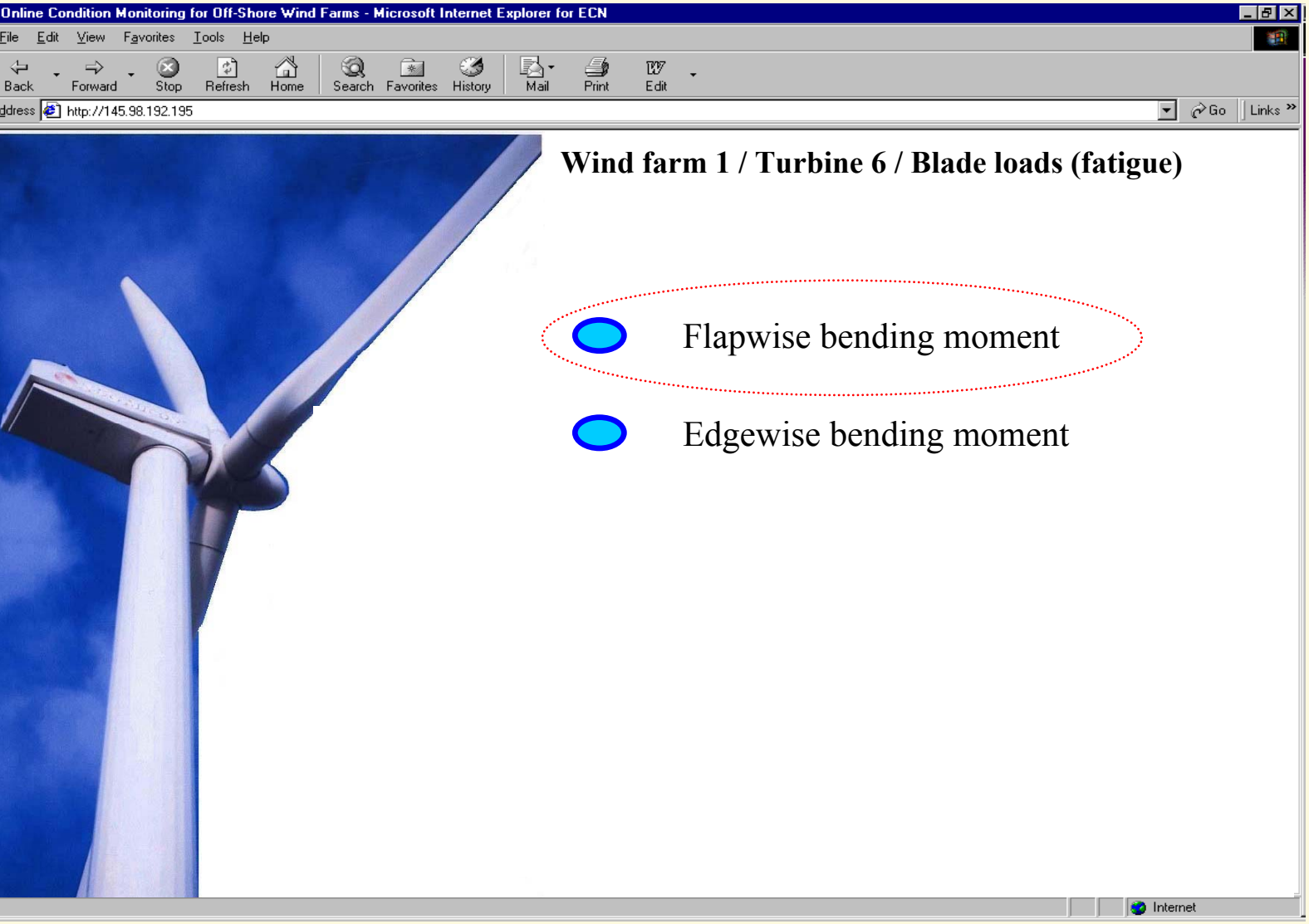
FOBM: Remote Access



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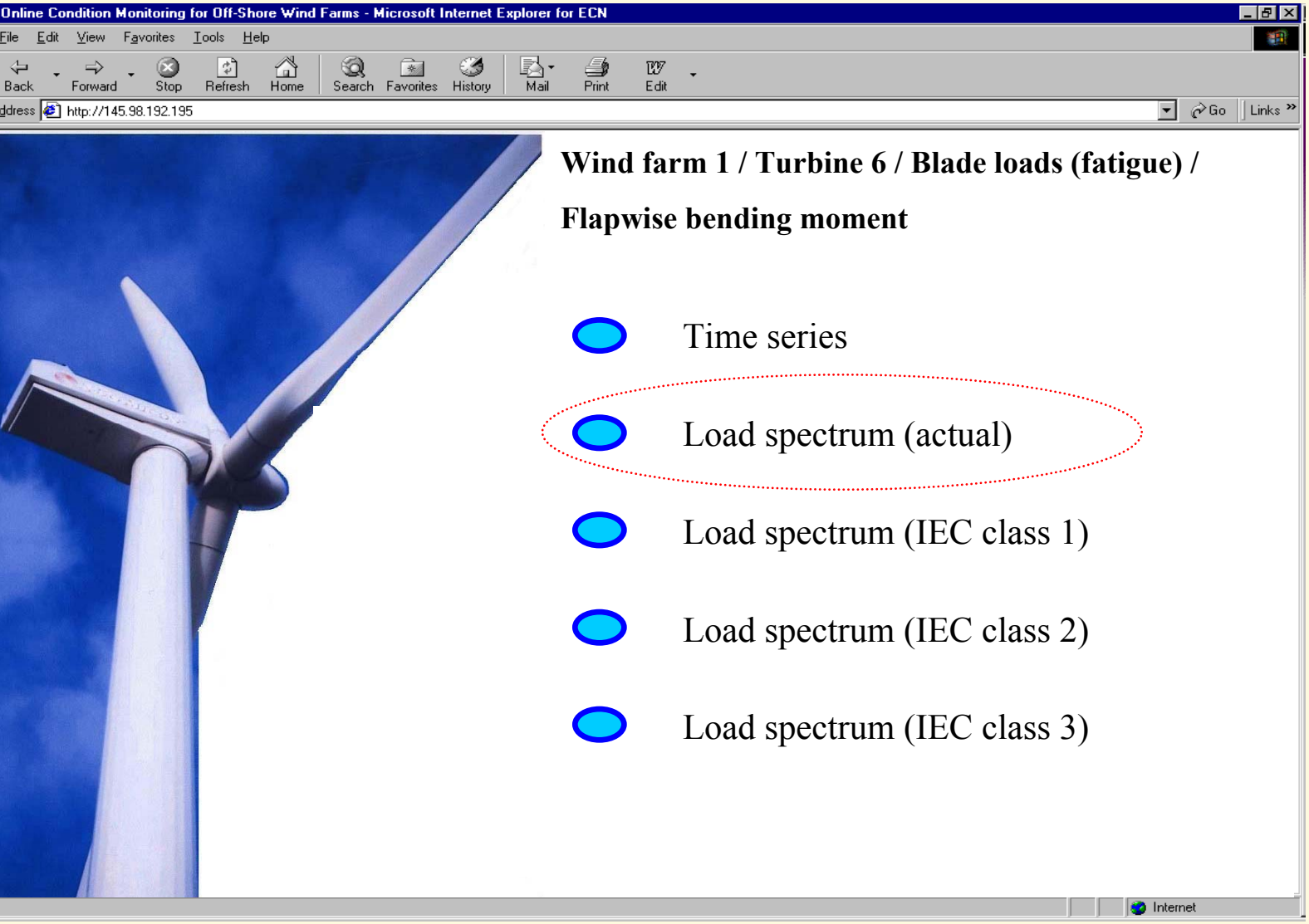

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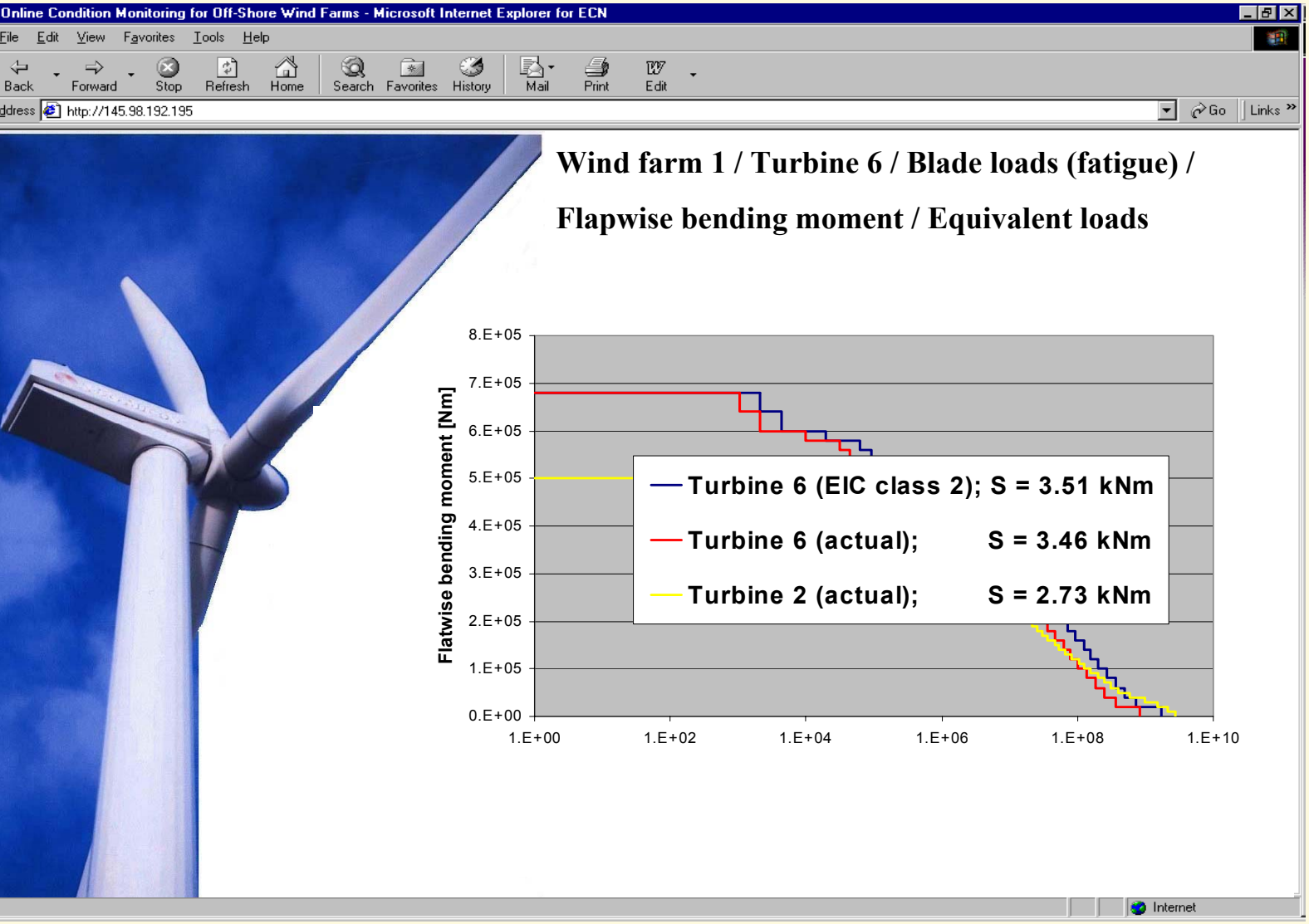

Equivalent loads:

$N = CS^{-m}$

N = fixed number of cycles

C, m = material properties

S = equivalent load

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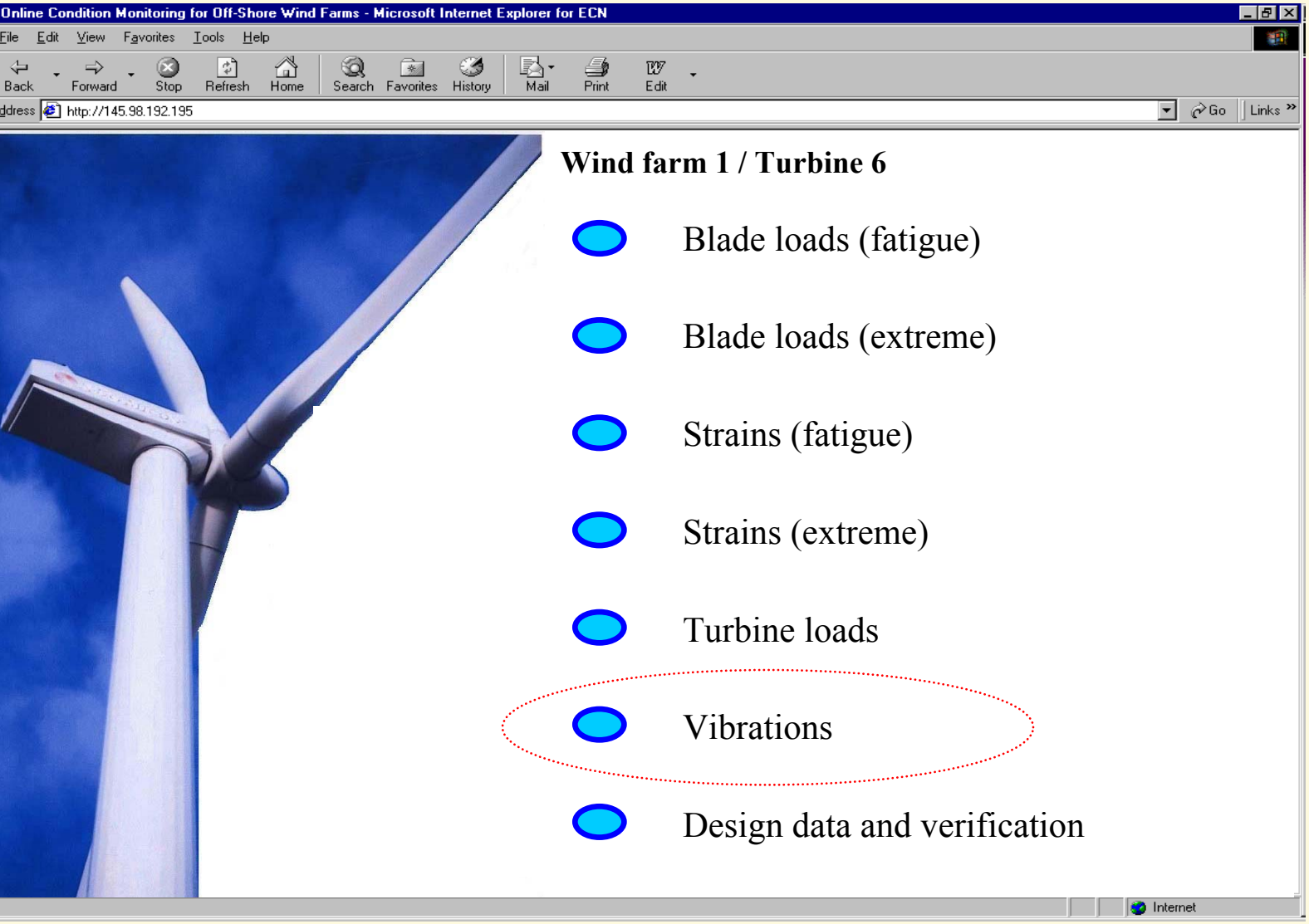
FOBM: Remote Access



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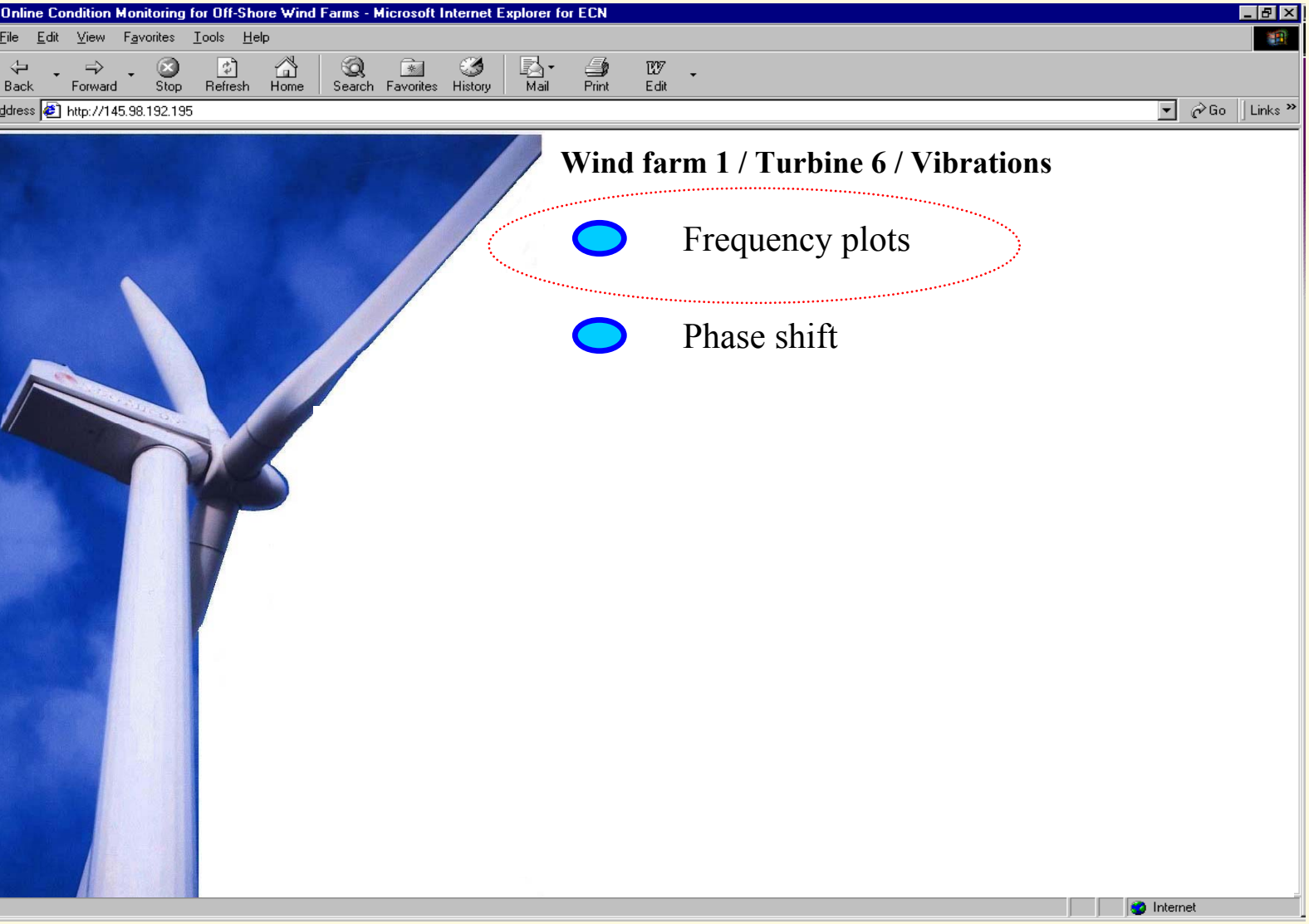

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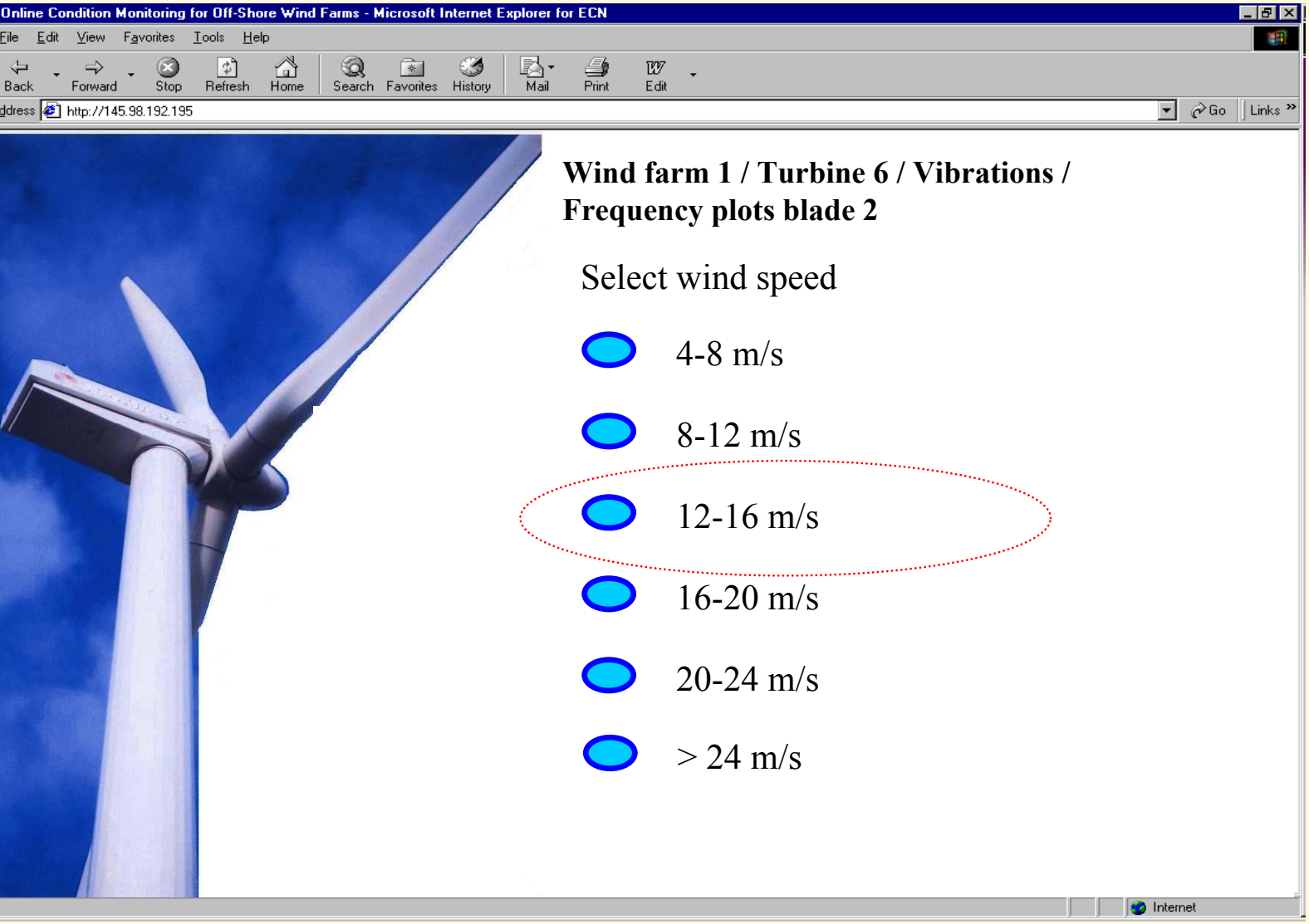

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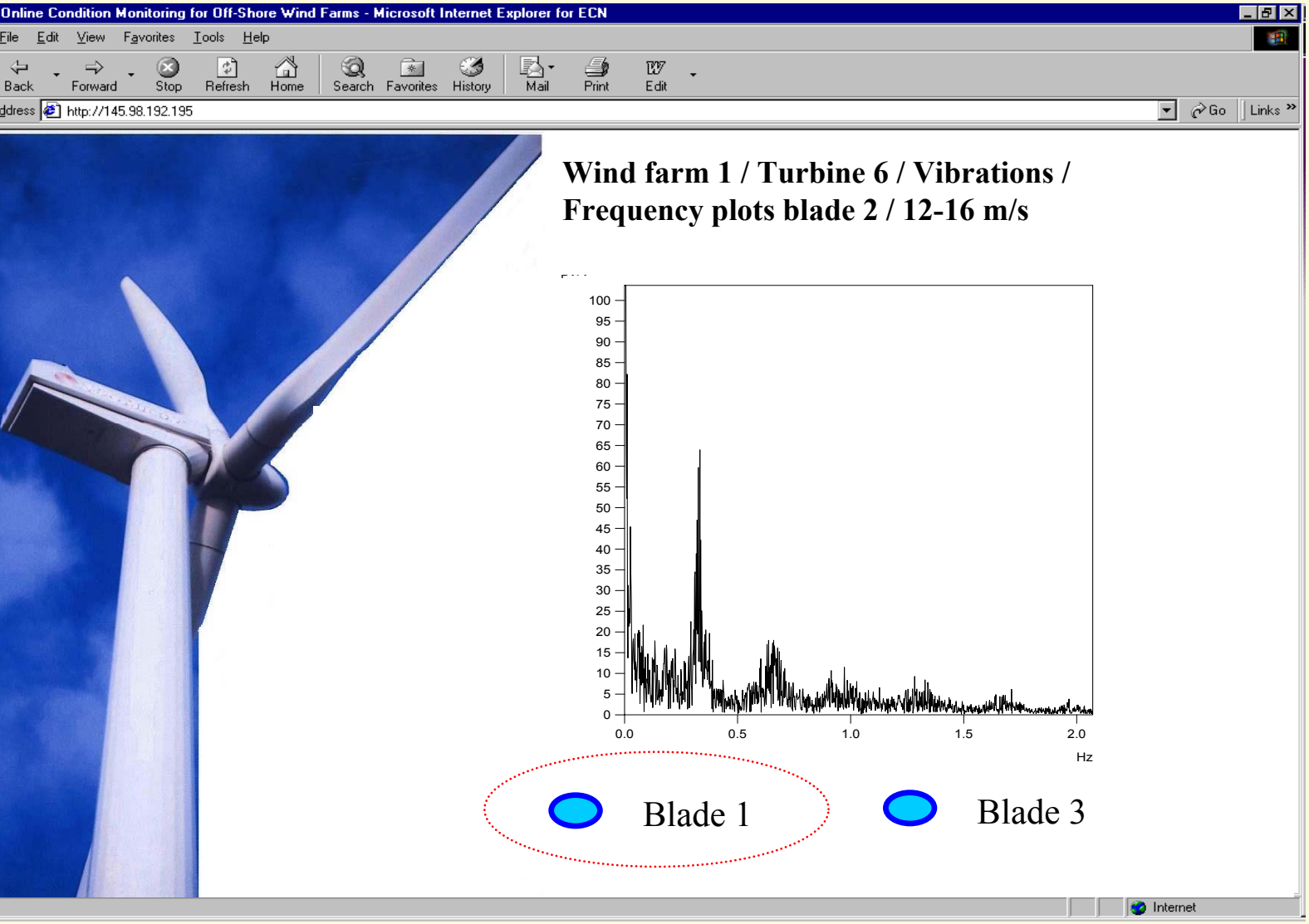

Natural frequency of blade 2 at 14 m/s wind speed

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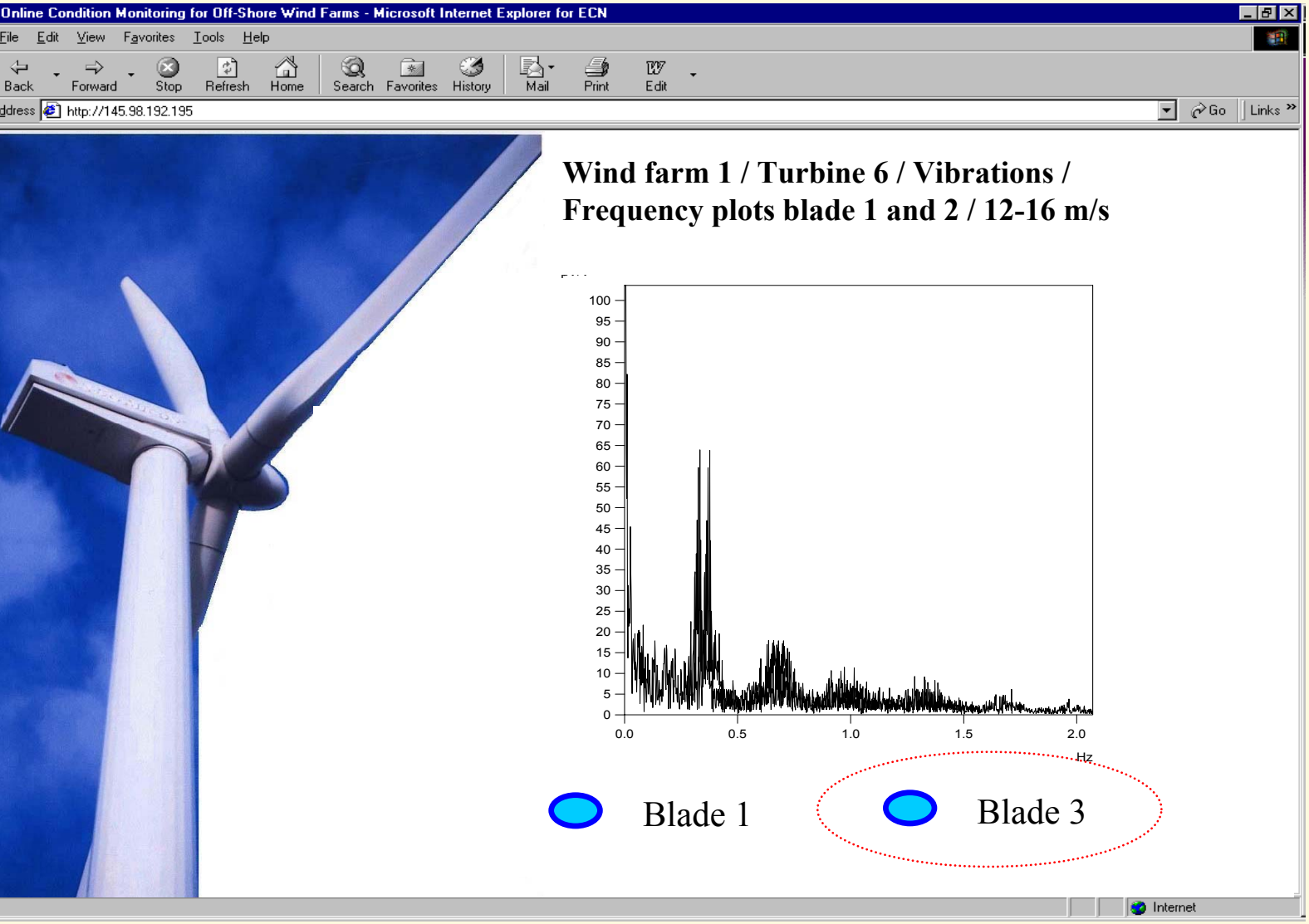
FOBM: Remote Access



Natural frequency of blade 2 and blade 1 at 14 m/s wind speed

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Any questions?

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